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Fusion Implementation

by

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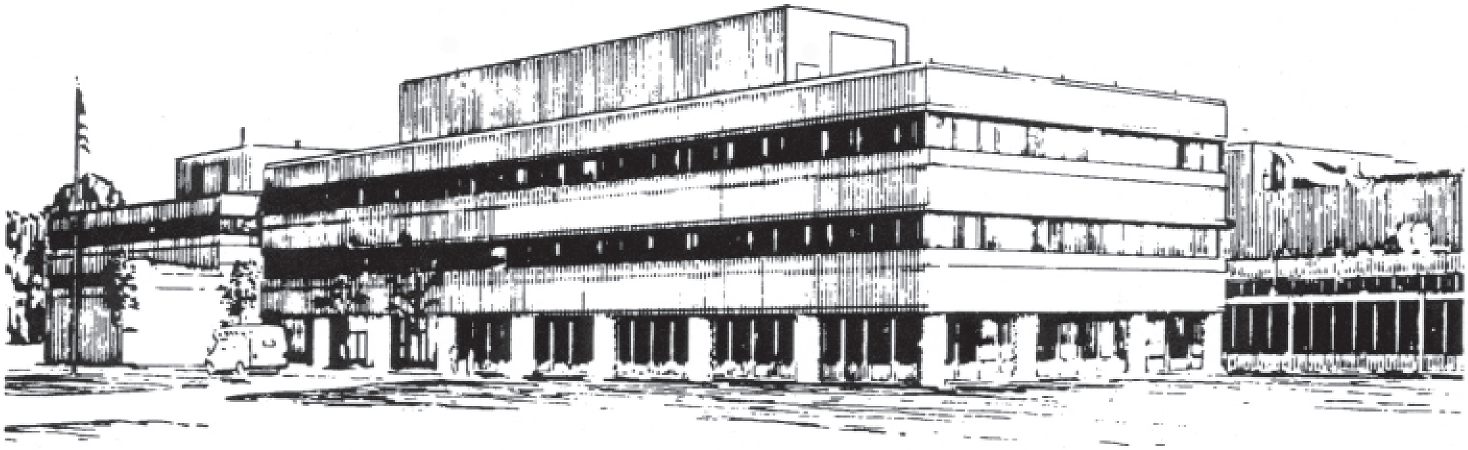

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Fusion Implementation

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Abstract-- **If a fusion DEMO reactor can be brought into operation during the first half of this century, fusion power production can have a significant impact on carbon dioxide production during the latter half of the century. An assessment of fusion implementation scenarios shows that the resource demands and waste production associated with these scenarios are manageable factors. If fusion is implemented during the latter half of this century it will be one element of a portfolio of (hopefully) carbon dioxide limiting sources of electrical power. It is time to assess the regional implications of fusion power implementation. An important attribute of fusion power is the wide range of possible regions of the country, or countries in the world, where power plants can be located. Unlike most renewable energy options, fusion energy will function within a local distribution system and not require costly, and difficult, long distance transmission systems. For example, the East Coast of the United States is a prime candidate for fusion power deployment by virtue of its distance from renewable energy sources. As fossil fuels become less and less available as an energy option, the transmission of energy across bodies of water will become very expensive. On a global scale, fusion power will be particularly attractive for regions separated from sources of renewable energy by oceans.**

I. INTRODUCTION

If the international fusion program meets its development goals then fusion will be part of a portfolio of energy sources during the last half of this century. It will likely be the case that this portfolio will be constrained by limits on carbon dioxide emissions. The mix of energy sources that make up this portfolio will depend in part on the systems aspects of the specific distribution system. These systems aspects will in turn depend on the uncontrolled availability of the power sources being used (e.g. wind). In addition regional factors such as the availability of primary energy resources (e.g. solar) will also play an important role. There will be regions that are more fertile for the introduction of fusion than other sources. Up until this point these factors have not been given serious consideration when developing fusion deployment scenarios. This report will illustrate some of the implications of deploying fusion reactors in a regional distribution system. We will focus on the Northeastern United States as an important region and on wind as one alternative. Wind power is chosen for illustrative purposes because it is relatively well developed and exhibits both temporal variations and regional resource limitations.

If fusion meets its development goals it will be a benign power source without regional limitations that would impede deployment within any distribution system. Provided that the cost of fusion power is competitive, the deployment of fusion reactors will depend to a significant extent on the regional “fertility” for other power sources.

II. REGIONAL FACTORS

As stated above we will focus on the Northeastern United States to illustrate regional factors and we will us wind power as a well developed alternative to fusion. The Northeast will be defined as the following states:

Connecticut
Delaware
Maryland
Massachusetts
New Jersey
Rhode Island
Maine
New Hampshire
Vermont
Virginia
New York
Pennsylvania
West Virginia

As a rough projection of electrical demand for this region we prorate the International Panel on Climate Control (IPCC) projections (IS 92a) according to present population [1]. This projection is shown in figure 1. To estimate the need for new non-emitting energy sources, we assume the limitations on emissions imposed by plateauing the atmospheric concentration of carbon dioxide at a level of 650 ppm. This curve is also shown in figure 1. We see from these projections that roughly 0.1 Tera Watts of new non-emitting power sources will be needed by the end of this century.

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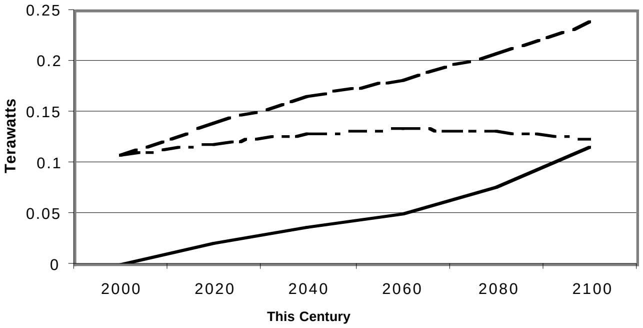

Fig. 1. Total electrical demand projections for the Northeastern United States along with the allowed power from fossil fueled plants if the atmospheric emissions are constrained to limit carbon dioxide in the atmosphere to 650 ppm. Also shown is the power from the associated non-carbon dioxide producing power plants.

As a basis for projecting wind power availability we use the resource estimates provided by Elliot, et al. [2]. Figure 2 shows plots of the wind power available as a function of distance from the coast measured directly east. The region considered is limited to states above the 37N parallel. A moderate wind speed (30 mph) is assumed along with two levels of environmental restriction on land use. These curves show the expected increase in wind power availability when approaching the Great Plains. 100,000 square kilometers translates to a little over 0.1 Tera Watts.

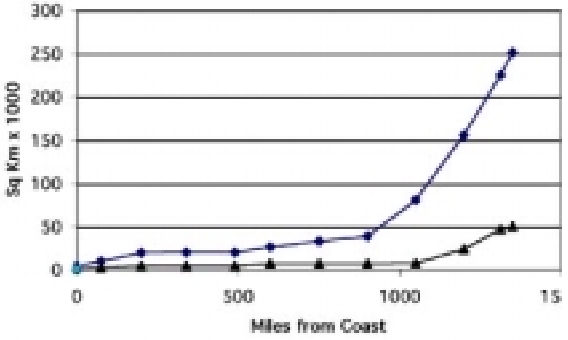

Fig. 2. Wind resources as a function of longitudinal distance from the Northeast coast for cases of low and significant environmental land exclusions.

If significant land use restrictions apply to wind power deployment, long distance transmission will be required between the Great Plains and the Northeast if wind is to be a significant source of power for this region. A likely scenario is for this power source to be used to supply regions closer to the Great Plains.

III. IMPACT OF TEMPORALLY VARIABLE ENERGY SOURCES

Again using wind as an example we will examine the consequence of temporally variable energy sources on a power distribution system performance. The primary value of a power unit in this system will be defined as its contribution to meeting peak demand. The contribution to periods of peak demand is the primary purpose for the capital investment in a power plant.

We assume an isolated power distribution system made up of 40 identical units with 0.9 uncontrolled availability. Increments of wind power will be added to this system from a source at one location, and the incremental increases in performance assessed. We will require that the system have a 0.9 probability of supporting each peak demand occurrence without a voltage reduction to reduce the demand. The power associated with a wind farm is the power averaged over a relevant season. We will assume a Rayleigh distribution [3] for the probability as a function of wind velocity. As a measure of value we will define a unit of credit as the fraction of a unit of the average power produced by the wind farm that can be used to replace a unit of high availability (e.g. 0.9 availability) central power (e.g. fusion or coal plant) while maintaining the probability of meeting peak demand at the 0.9 level.

Figure 3 shows a plot of the credit as a function of the fraction of the total distribution system that is represented by the wind unit. For low levels of wind application the variable system will get approximately full credit for the power installed. However, when the installed wind power level increases relative to the overall capacity of the distribution system, the value of the wind system measured against contributions to meeting peak demand drops rapidly.

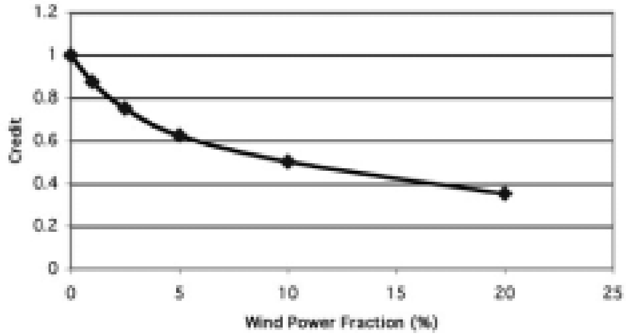

Fig. 3. The Credit that a wind power source at one location would receive relative to a 0.9 availability central power plant, is shown as a function of the fraction of the distribution system represented by the wind source.

IV. IMPACT OF ENERGY STORAGE

It is commonly assumed that energy storage will alleviate the problem of variable power sources, if one is willing to pay for the construction and operation of the storage system. In most cases this is not true. To illustrate the systems aspects of energy storage consider Figure 4. We again recognize the fact that the important time to consider is during periods of peak demand. These periods occur during the day and usually in the summer. The storage system would be charged at night during a period of reduced demand. During this period, power is available to charge the storage system without depending on the wind power as long as the wind power is not too large a fraction of the total distribution system. If it is too large a fraction, problems could be encountered in meeting off peak demand. With the storage system charged for a period of peak demand, all available power sources will be callable including the storage and wind power. The wind power contribution will again be governed by figure 3 irrespective of the existence of the storage system.

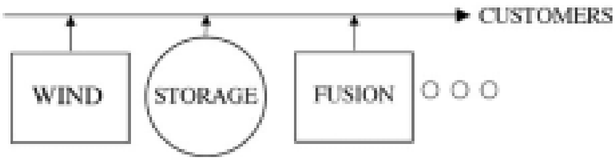

Fig 4. A conceptual power distribution system including energy storage.

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